OBSERVATIONS OF STRATOSPHERIC TEMPERATURE CHANGES COINCIDENT WITH THE RECENT ANTARCTIC OZONE DEPLETIONS

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1. INTRODUCTION

A high degree of correlation between the recent decline in Antarctic total ozone and cooling of the stratosphere during Austral spring has been noted in several recent studies (e.g., Sekiguchi, 1986; Angel, 1986). This study analyzes the observed temperature trends in detail, focusing on the spatial and temporal aspects of the observed cooling. Ozone losses and stratospheric cooling can be correlated for several reasons: 1) ozone losses (from an unspecified cause) will directly reduce temperatures due to decreased solar ultraviolet absorbtion (Shine, 1986), and/or 2) changes in both ozone and temperature structure due to modification of stratospheric circulation patterns (Mahlman and Fels, 1986). In order to scrutinize various ozone depletion scenarios, detailed information on the observed temperature changes is necessary; our goal is to provide such data.

The data used here are National Meteorological Center (NMC) Climate Analysis Center (CAC) derived temperatures, covering 1000–1 mb (0–48 km), for the period 1979–1987. Discussions on data origin and quality (assessed by extensive comparisions with radiosonde observations), along with other details of these observations, can be found in Newman and Randel (1988).

2. OBSERVED TEMPERATURE TRENDS

Figure 1 shows October average values of total ozone and 70 mb (~19 km) temperature at the South Pole for 1979–1987 (the total ozone data is from Total Ozone Mapping Spectrometer (TOMS) observations, as discussed in Schoeberl et al. (1986)). Strongly correlated interannual variability is observed in both variables in Fig. 1, along with a general decline over 1979–1987. The dashed lines show linear slopes calculated over 1979–1986, and we use similar linear trend analysis as an objective method to locate regions and times of large temperature changes over this period. (We note here that linear trends over eight years of data should not be interpreted as monotonic climate variations—this is discussed below in light of longer records of observations.)

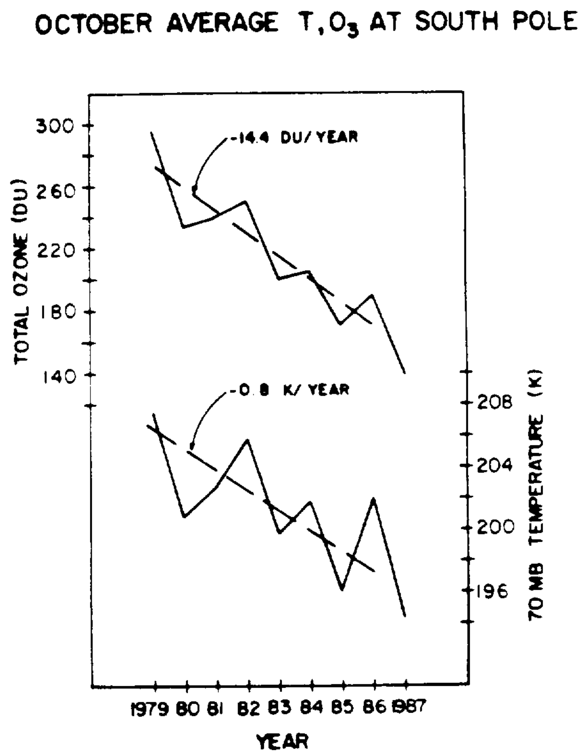

Fig. 1. October average values of total ozone (top) and 70 mb temperature (bottom) at the South Pole over 1979–1987. The linear trends of each series over 1979–1986 are indicated by dashed lines.

Figure 2 shows polar orthographic plots of 1979–1986 trends in October average total ozone (left), and 70 mb (~19 km) temperature (right); here the trends have been calculated separately at each horizontal grid point. The similarity in patterns and details between the ozone and temperature trends is intriguing; note not only the strong negative trends in both quantities centered near the east coast of Antarctica, but correlated positive trends west of South America near 50°S. These highly spatially correlated trends illustrate the coherent nature of interannual ozone-temperature variations.

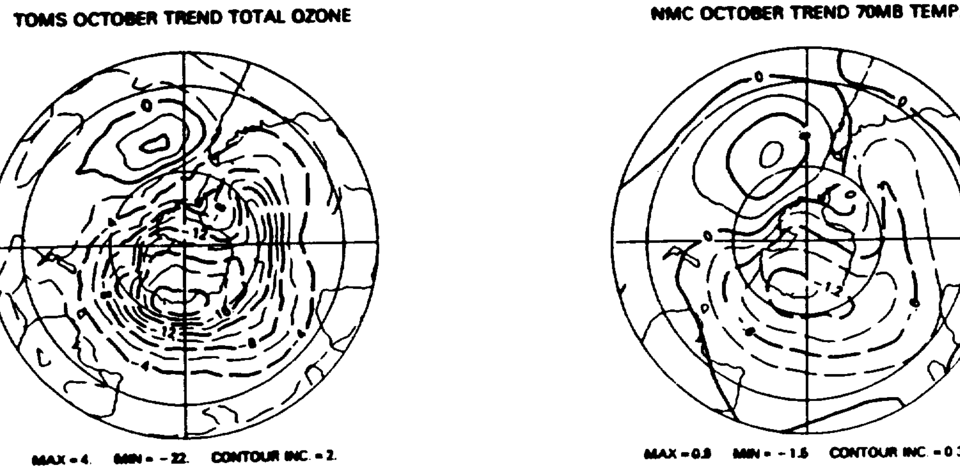

Fig. 2. Polar orthographic plots of 1979–1986 linear trends in October average total ozone (left) and 70 mb temperature (right). The outer latitude is 20° S. These diagrams are constructed by calculating the linear trend independently at each horizontal grid point. Units of DU/year and K/year, respectively.

Further spatial and temporal characteristics of the NMC derived temperature trends are illustrated in Fig. 3, which show meridional cross sections of trends in zonal mean temperature (because of interannual variability in data acquisition procedures, trends in Fig. 3 above 10 mb are not reliable, and should be viewed skeptically). Trends calculated in Fig. 3 include the 1987 data. The strongest zonal mean cooling is observed in October poleward of 40°S over 200–10 mb, and in November poleward of 60°S over 200–30 mb.

A latitude-time section of the zonal mean temperature trends at 50 mb (~21 km) is shown in Fig. 4b to highlight the temporal evolution (a low pass filter has been applied to the data in Fig. 4 to remove fluctuations with periodicities below 50 days). Also shown in Fig. 4a is the 1979–1987 mean temperature evolution at 50 mb. The trends (Fig. 4b) highlight strongest polar cooling in October and November, with a mid-latitude cooling band extending into December (note the lack of high latitude cooling beyond November), along with high latitude warming during August-September. Comparison of the trends (Fig. 4b) with the mean evolution (Fig. 4a) show that although the spring warming progresses somewhat slower during October-November (*i.e.*, the negative trends), temperatures in high latitudes following the final warming (*i.e.*, beyond November) have changed little over this period.

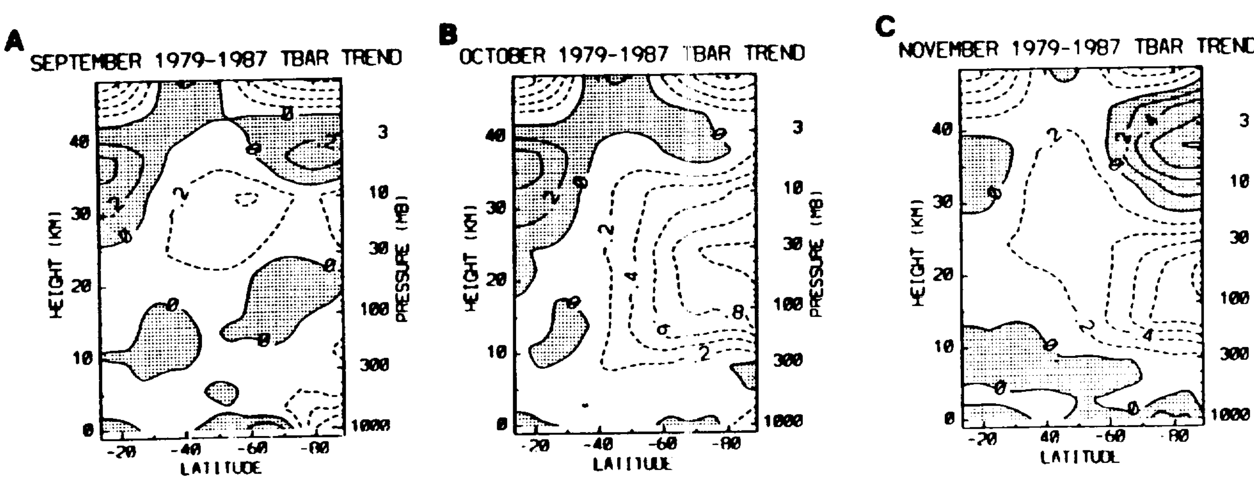

Fig. 3. Linear trends over 1979–1987 of zonal mean temperature during (a) September, (b) October, and (c) November. Units of K/year.

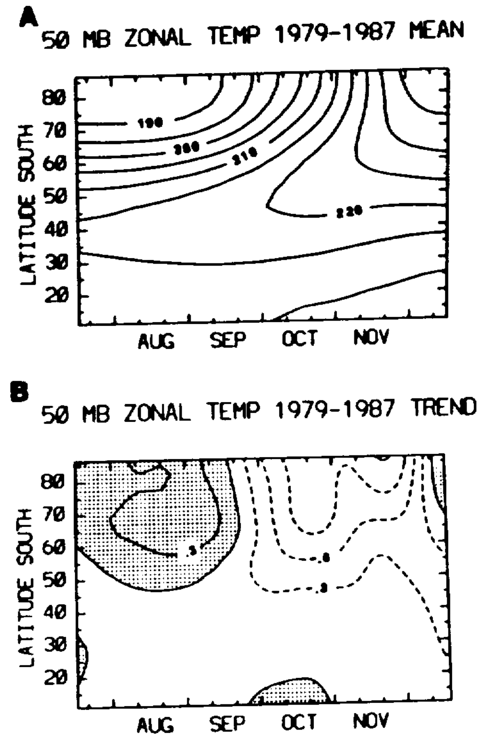

Fig. 4. Latitude-time sections at 50 mb of the (a) zonal mean temperature (K) averaged over 1979-1987, and (b) 1979-1987 linear trend in zonal mean temperature (K/year). These diagrams have been constructed using a low pass filter applied to daily data.

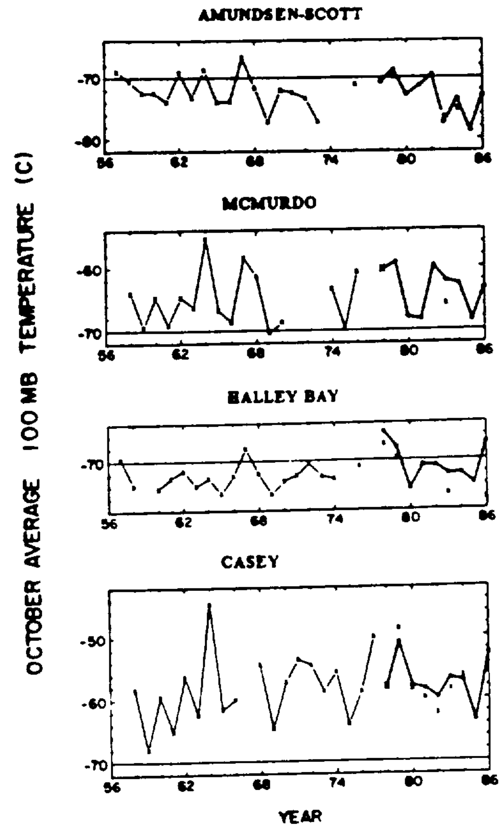

Fig. 5. Time series of October average 100 mb temperature (° C) at four selected stations around Antarctica. The x's and light lines denote monthly mean radiosonde observations, while the heavy lines over 1978-1986 are from the NMC analyses.

To evaluate longer term temperature fluctuations, and check on the NMC data quality, we have studied available monthly mean stratospheric radiosonde observations (RAOBS). Figure 5 shows time series of 100 mb October average temperatures at four selected Antarctic stations (these four have relatively complete RAOB records over 1957–1984—more extensive comparisons are shown in Newman and Randel, 1988). Although direct NMC RAOB comparions are restricted to 1978–1984, overall good agreement is seen between the two data sets (in particular, similar sized interannual differences). Furthermore, inspection of these longer term records shows no evidence for monotonic climatic trends, in spite of the decrease in temperatures seen over 1979–1986. These data lead to the conclusion that linear trends derived from limited time samples (such as the eight years studied here) should not be treated as representative of long term variations.

3. SUMMARY

Large decreases in October average total ozone in the Southern Hemisphere over 1979-1987 are highly spatially correlated with contemporaneous cooling of the lower and middle stratosphere. This study analyzes the spatial and temporal nature of the observed temperature changes, with the following main results:

1) Stratospheric polar cooling is strongest in October-November, extending over 200–10 mb (11–32 km) (Figs. 3 and 4b), and the patterns are highly zonally asymmetric (Fig. 2). Local temperature differences between October 1979 and October 1986 of 12K and 16°K are observed at 70 and 30 mb, respectively, coincident with a local column ozone decrease of 160 DU. Seasonal and zonal mean estimates of temperature changes result in substantial underestimates.

2) Inspection of the 1979–1987 trends in light of the longer historical record from RAOB data shows no evidence of monotonic climatic variations; the 1979–1987 temperature declines are not distinguishable from other decadal time scale fluctuations.

References

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